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WINTER AND SUMMER MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

Richard W. Johnson

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Scientific Report No. 15
June 1981

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Contract Monitor, Major John D. Mill, USAF
Optical Physics Division

Prepared for
Air Force Geophysics Laboratory, Air Force Systems Command
United States Air Force, Hanscom AFB, Massachusetts 01731

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[illegible] REPORT [illegible]

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Atmospheric Scattering Coefficient
Surface Visibility
[illegible]

This report presents measurements of atmospheric volume scattering coefficients collected during [illegible] low altitude flights made during the Winter and Summer seasons of 1976 [illegible] different European locations. The measurements were conducted during an instrumented aircraft [illegible] approach and landing at its staging airbase. The measurements were made using a [illegible] spectral response and thus are suitable for comparison with data associated with standard [illegible] determinations of airfield visibility.

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20 ABSTRACT continued

The data illustrate that in twenty-six of twenty-nine cases, there was little or no significant variation in the value of scattering coefficient as the aircraft approached the surface from an altitude of several hundred meters.

AFGL-TR-81-0154 SIO Ref. 81-26

WINTER AND SUMMER MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

SUMMARY

This report, which describes portions of the Visibility Laboratory's Project OPAQUE effort, was prepared under AFGL Contract F19628-78-C-0200. It contains a presentation of 29 low altitude scattering coefficient profiles and related meteorological data that were measured during the Winter and Summer seasons of 1978 at four different geographical locations. The measurements were conducted during an instrumented aircraft's approach and landing at four of the staging bases associated with the overall OPAQUE program, Johnson *et al* (1979).

The nephelometer measurements of total volume scattering coefficient which are presented in this report were made using a pseudo-photopic spectral response having a mean wavelength of 557nm, and are thus suitable for comparison with data associated with standard visual determinations of airfield visibility. The temperature and dewpoint temperature measurements were made using an AN/AMQ-17 aerograph and a Cambridge Model 137-C3 Aircraft Hygrometer System. Measurements of horizon and terrain luminances which were also made during these aircraft descents are not included in this report but are available in the Visibility Laboratory's basic data base should their subsequent analysis become desireable.

The reported data illustrate that in twenty-six out of twenty-nine cases, there was little or no significant variation in the photopic scattering coefficient as one approaches the surface from an altitude of several hundred meters. Thus modelling approximations of low altitude haze properties based upon near surface measurements are in general appropriate for the range of meteorological conditions extant during these flights.

A

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WINTER AND SUMMER MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

Richard W. Johnson

1. INTRODUCTION

In the increasingly sophisticated world of electro-optical detection, search, and guidance, the requirement for establishing and predicting atmospheric influences on system performance continues to develop as a primary operational necessity. It is in support of this general context that the Visibility Laboratory in cooperation with, and under the sponsorship of the Air Force Geophysics Laboratory has maintained an extensive program of airborne optical and meteorological measurements. In recent years this program has been conducted as an independent but cooperative effort [Johnson *et al.* (1979)] in conjunction with the NATO program OPAQUE (Optical Atmospheric Quantities in Europe), Fenn (1978). During the two year interval spanning the years 1977 and 1978, over 80 missions were flown documenting the vertical structure of the visible spectrum total volume scattering coefficient in the lower troposphere. Since a thorough awareness of this vertical structure is essential to the prediction of atmospheric influences on contrast transmittance through this regime, these data have been presented in a series of technical reports, the most recent of which is entitled "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1978", Johnson and Gordon (1980).

The optimum use of the experimental data presented in reports such as Johnson and Gordon (1980) is surely to establish the baseline assessment of those optical characteristics most influencing slant path contrast transmittance, and to develop from these assessments realistic predictive models. An initial effort in this model development, using both surface and profile data from the OPAQUE program is discussed in Johnson *et al.* (1979), and the further application of these data to contrast transmittance modelling is illustrated by Hering (1981).

A necessary but unfortunate artifact of the data presented in the report series referred to above, Johnson and Gordon (1980) etc. is that the measurements were always terminated at some significant altitude above ground level. A necessary condition imposed by the safety of flight regulations which apply to a civil air space, and an unfortunate condition due to the extreme sensitivity of slant path contrast transmittances to variations in the near surface haze conditions. Thus, even though the structure of the atmospheric scattering coefficient profile has been well documented within the altitude regime between 6 km and about 1 km above ground level, the true character of the near surface layer has been relatively undetermined. Several methods of extrapolation from the lowest measured data value have been used to identify the most probable values of scattering coefficient within this region, as have intermittent instances of interpolation between airborne and surface measurements when both were available. Obviously, neither of these techniques addresses the determination of the shape of the profile within the first kilometer above the surface. Consequently, there exists a significant degree of uncertainty in how one should properly define this altitude regime when attempting to calculate or predict its optical properties. This uncertainty is particularly troublesome when one addresses operational scenarios involving low flying systems whose mission depends upon the adequate performance of its electro-optical devices.

The data contained in this report are intended to reduce, at least in part, the uncertainties in the structure of the near surface scattering coefficient profile. These data, identified in Table 1.1, represent measurements made following each experimental data flight during the instrumented aircraft's approach and landing sequences. Thus the measurements were made in the specific region of interest, *i.e.* between the approach pattern altitude of approximately 1200 ft and the surface, and can be used directly to identify the optical characteristics of this tactically critical transition zone. The flights indicated in Table 1.1 are all from the OPAQUE IV and V deployments, Johnson and Gordon 1979 and 1980, and thus represent only a sub-set of the total available data base. A second report, currently in preparation, will present similar data for the predominantly Spring and Fall time periods.

Table 1.1. Flight Identification Data

Aerodrome Identification	Flight No	Flight Date	Landing Time (GMT)
Sigonella, Sicily	432	03 Feb 78	150001
37°24'N 14°55'E	433	17 Feb 78	130853
24m MSL	434	18 Feb 78	140005
	460	02 Aug 78	154910
	461	03 Aug 78	124724
	462	05 Aug 78	132230
	463	07 Aug 78	134112
Wunstorf, Germany	451	22 Mar 78	144535
52°28'N 09°25'E	452	23 Mar 78	160830
57m MSL	454	28 Mar 78	141440
	456	31 Mar 78	163702
	465	14 Aug 78	153657
	466	15 Aug 78	134150
	468	21 Aug 78	131440
	469	22 Aug 78	160952
Memmingen, Germany	435	23 Feb 78	104356
47°59'N 10°13'E	436	23 Feb 78	152402
634m MSL	437	27 Feb 78	135823
	439	01 Mar 78	145643
	471	11 Sep 78	092904
	473	11 Sep 78	163609
Mildenhall, England	443	09 Mar 78	155711
52°22'N 00°29'E	444	11 Mar 78	162448
10m MSL	445	13 Mar 78	132659
	447	15 Mar 78	150413
	448	17 Mar 78	144958
	475	15 Sep 78	174646
	476	16 Sep 78	153834
	477	18 Sep 78	152524

Note GMT times are indicated in Hours-Minutes-Seconds

2. PROCEDURES & INSTRUMENTATION

The general flight sequences conducted during the OPAQUE measurement program have been reported in several preceding reports as noted in bottom row entries of Table 2.1. In these earlier reports, measurements of atmospheric volume scattering coefficient and natural irradiance levels were presented for a broad variety of geographical and seasonal conditions. The general locale for these data missions is illustrated in Fig. 2-1 which has been abstracted from Johnson *et al.* (1979). The aerodromes at which the approach data were measured are indicated by the symbol, ★.

The instrumentation used during these flight episodes has been described adequately in the previously referenced reports [Johnson and Gordon (1980), etc.] and will not be further elaborated upon herein. Suffice it to say that the entire instrument system was mounted on an Air Force C-130 aircraft and included, but was not limited to, the following listed items:

a. A multi-channel, multi-spectral nephelometer for the measurement of atmospheric total volume scattering coefficient and directional scattering functions,

b. multi-spectral scanning radiometers for the measurement of sky and terrain radiances,

c. a multi-spectral, two channel flat plate irradiometer for the measurement of upwelling and downwelling irradiance levels, and

d. meteorological transducers for the measurement of ambient temperature, dewpoint temperature and atmospheric pressure.

A special measurement sequence was associated with most flights discussed in these earlier reports, but its resultant data were not included as part of the standard flight package, nor included in those reports. These specialized data resulted from having the airborne optical, meteorological, and data logging instrumentation operational during the aircraft's landing approach and touchdown. Thus, since the aircraft was staging out of an airfield generally remote from the standard OPAQUE flight tracks shown in Fig. 2-1, two separate and independent data sets were collected during most missions. The

Table 2.1. Geographical and Seasonal Distribution of Low Altitude Scattering Coefficient Profiles

Aerodrome Locations (see Fig. 2-1)	Attempted Low Altitude Data Sequences				
	Spring, 1976	Fall, 1976	Summer 1977 & 1978	Winter 1978	Totals
Sigonella, Sicily	0	0	4*	4*	8
Lorient, France	0	4	3	0	7
Memmingen, Germany	0	0	3*	6*	9
Wunstorf, Germany	3	5	13*	4*	25
Soesterberg, Netherlands	1	0	0	0	1
Mildenhall, England	4	0	1*	6*	11
Vaerlose, Denmark	2	1	4	0	7
Totals	10	10	30	20	70
Related Data Reports	AFGL-TR-77-0078	AFGL-TR-77-0239	AFGL-TR-78-0168 AFGL-TR-80-0207	AFGL-TR-79-0159	AFGL-TR-79-0287

*Asterisk indicates those sub sets from which the data in this report were chosen

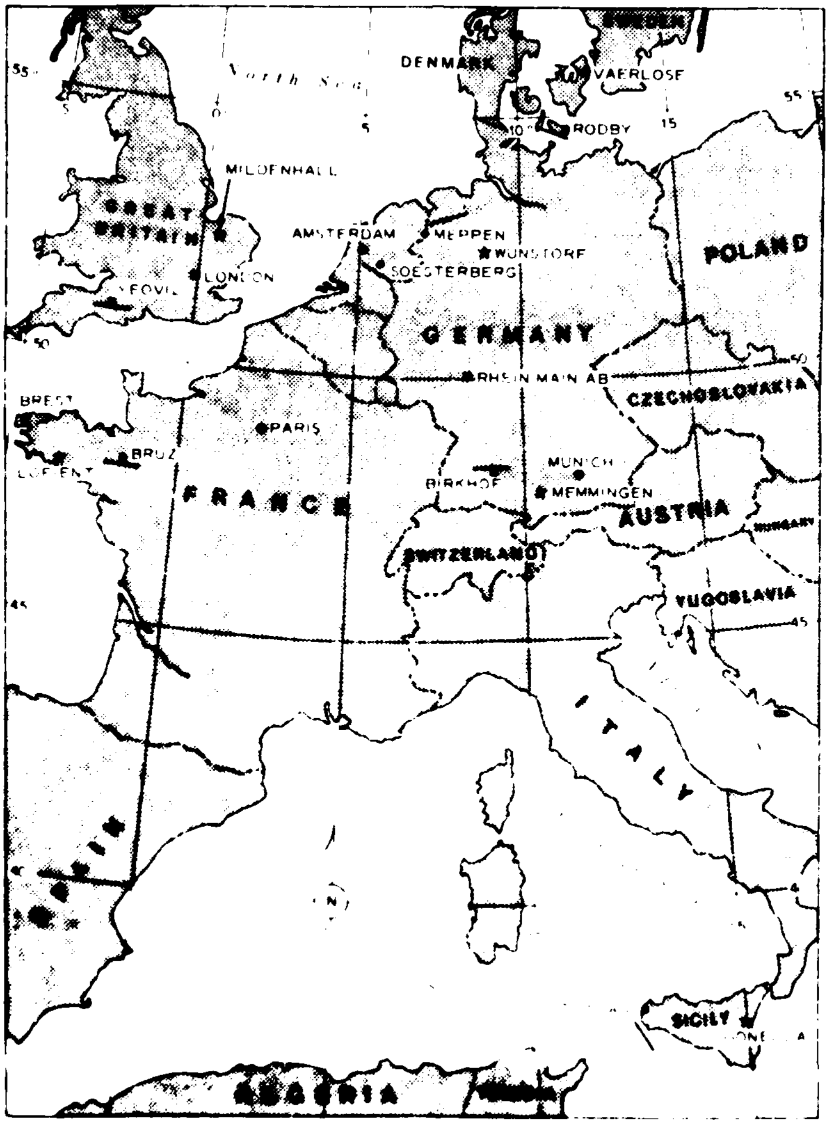


Fig. [illegible] Typical OPAQUE Flight Tracks

first was the rather extensive multi-spectral set of measurements made along the indicated tracks between 6 and [illegible] kilometers in altitude, and the second was the smaller, more selective set made at the local staging base between about 0.7 and 0.0 kilometers. This second set of measurements, made only in the photopic spectral band, is nominally referred to as the APPROACH data.

There were several special considerations imposed during the collection of the APPROACH measurements which distinguish these data from the larger set previously reported. In general they were as follows:

1. Measurements were made in only one spectral band. During the APPROACH descent from approximately 1200 ft AGL to the surface, the structural character of the scattering coefficient profile was the datum most desired. Thus the integrating nephelometer was pre-set to make continuous measurements of the photopic (λ = 557nm) total scattering coefficient throughout the descent. By not switching optical filters, all measurements were accomplished with the optimum spatial resolution.

2. Measurements were made with pre-set, static optical configurations. This consideration was also imposed

to eliminate unnecessary time sharing sequences and thus optimize the detection of profile variations during the relatively short descent episodes. Thus the nephelometer was pre-set to measure total scattering coefficient only without cycling through the directional channels; the scanning radiometers were pre-set to stare at the sky and terrain directly ahead of the aircraft, approximately 5° above and 5° below the local horizon; and the dual channel irradiometer was pre-set to measure total downwelling irradiance throughout the descent.

3. Data logging began shortly before the initiation of the aircraft's final descent for landing and continued throughout the descent and actual aircraft touchdown on the runway. Some editing has been required to eliminate spurious pre-descent and post-landing data which were adversely influenced by abnormal aircraft attitudes during initial line up and prop reversal influences during roll-out.

Post deployment data processing of these data has been handled in a manner similar to that described in Johnson and Gordon (1979). Calibration data for each deployment set is the same as was used for the parent data sets as referenced in each of the Related Data Report entries of Table 2.1. Readers are referred to these more detailed reports for supplementary background information where required.

3. WEATHER SUMMARY

The weather conditions existing during each of the flight episodes from which the APPROACH profiles have been extracted are discussed in detail in Johnson and Gordon 1979 and 1980. These parent reports include data from daily surface and 500 millibar charts, surface observations, pilot reports, vertical cross sections and radiosonde launches. The bulk of these data were provided by the U.S. Air Force Environmental Technical Applications Center (USAF/ETAC) at Scott Air Force Base, and the National Oceanographic and Atmospheric Administration via the National Climatic Center in Asheville, North Carolina.

Comparisons between the C-130 and RAOB airborne measurements of temperature, dewpoint temperature, and the derived values of relative humidity for each of the winter and summer flights preceding these APPROACH episodes have been made in the parent reports referenced above. However, several additional comparisons are summarized herein which relate more directly to the actual landing circumstances.

Measured values of temperature (t), dewpoint temperature (dp), and atmospheric pressure (p), that were recorded at the exact moment of landing touchdown have been compared with the equivalent values reported by the host aerodrome for eighteen of the flights reported in Section 4. These flights were those for which the flight dynamics data permitted a specific and unambiguous determination of the exact instant of landing. Those flights for which the landing time was for any reason not specific were not included in the comparison even though their data might in fact be suitable in all other respects. These comparisons are listed in Table 3.1. In all cases the differences, Δt, Δdp and Δp represent the aerodrome measurement minus the C-130 measurement.

The data summarized in Table 3.1 indicate that the airborne and aerodrome measurements were on the average in reasonable agreement. The temperature data indicate a systematic difference of about 1°C between the C-130 and aerodrome measurements. However, the dewpoint and pressure measurements indicate no similar systematic offset.

Table 3.1 Comparison of Aerodrome & C-130 Data (Measurements During Landing)

Aerodrome	Flight Number	Temperature Δt (°C)	Dew Point Δdp (°C)	P[illegible]
Sigonella	432	+1.9	[illegible]	
	433	+0.2	[illegible]	
	461	+2.[illegible]	[illegible]4.4	[illegible]
	463	+[illegible]	[illegible]	
Wunstorf	451	+0.8	[illegible].4	[illegible]
	454	+4.[illegible]	[illegible]	
	468	+[illegible]	[illegible]	
	469	+[illegible]	[illegible]	
Memmingen	435	+0.2	[illegible]	[illegible]
	436	+0.7	[illegible]	[illegible]
	437	+3.0		[illegible]
	47[illegible]	+1.9	[illegible]1.9	[illegible]
Mildenhall	443	+2.4	+0.8	
	444	+1.[illegible]	[illegible]	[illegible]
	445	+0.9	[illegible]	
	475	+0.[illegible]	[illegible]	
	476	+1.[illegible]	[illegible]	[illegible]
	477	+1.2	[illegible].4	
Overall Average	18 Flights	[illegible]		

Note

1. Δt is positive for all 18 flights, implying systematically low measurement by the C-130 system.

2. Δdp & Δp reflect both positive and negative values intermixed throughout the 18 flights.

Since the staging aerodromes for most of these flights were generally remote from the primary data tracks, selected supplemental weather data related specifically to the APPROACH site have been included herein. Short summaries of the meteorological observations taken at the staging aerodrome, at or near the time of landing, are presented in Table 3.2. A glossary of the most often used symbols is included in Appendix A for the reader's convenience. All data were reported in Greenwich Civil Time (GCT), which is equivalent to Greenwich Mean Time (GMT), the terminology used in Table 3.2.

Table 3.2a Sigonella, Sicily Standard Meteorological Data Sheet [illegible]

Summer [illegible]

Time (GMT)	Cloud Cover	Visibility (Kilometers)	Weather and Obstruction to Vision	Temp (°C)	Dewpoint (°C)	Wind Direction (Deg)	Wind Speed (Kts)	Remarks
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Winter [illegible]

Time (GMT)	Cloud Cover	Visibility (Kilometers)	Weather and Obstruction to Vision	Temp (°C)	Dewpoint (°C)	Wind Direction (Deg)	Wind Speed (Kts)	Remarks
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 3.2b Memmingen, Germany Standard Meteorological Data Sheet [illegible]

Summer [illegible]

Time (GMT)	Cloud Cover	Visibility (Kilometers)	Weather and Obstruction to Vision	Temp (°C)	Dewpoint (°C)	Wind Direction (Deg)	Wind Speed (Kts)	Remarks
Flight No. C-471 Date [illegible] September [illegible]								
[illegible]	Cloud Data Unknown			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Flight No. C-473 Date [illegible] September [illegible]								
[illegible]	Cloud Data Unknown			[illegible]		[illegible]	[illegible]	[illegible]

Winter [illegible]

Time (GMT)	Cloud Cover	Visibility (Kilometers)	Weather and Obstruction to Vision	Temp (°C)	Dewpoint (°C)	Wind Direction (Deg)	Wind Speed (Kts)	Remarks
Flight No. C-435 Date 21 February 1978								
0952	Cloud Data Unknown	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Flight No. C-436 Date [illegible] February 1978								
[illegible]	Cloud Data Unknown	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Flight No. C-437 Date [illegible] February 1978								
[illegible]	Cloud Data Unknown	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Flight No. C-439 Date [illegible] March 1978								
[illegible]	Cloud Data Unknown	[illegible]	H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table [illegible]

4 DATA PRESENTATION

4.1 Data and Flight Summary

During the summer of 1978 (2 Aug through 26 Sept) twenty flights were made in northern Europe of which nineteen contained usable profile data. These data were reported in Johnson and Gordon (1980). Of these nineteen, thirteen contained acceptable approach profiles. These thirteen flights are listed in Table [illegible].

During the succeeding winter (1978 [illegible] through [illegible] Mar) twenty seven flights were made in the same European regions of which [illegible] contained usable profile data. These data were reported in Johnson and Gordon (1979). Of these [illegible] contained acceptable approach profiles which are listed with the [illegible] are described in Table [illegible].

4.2 Description of Data Tables and Graphs

[illegible] data [illegible] the APPROACH sequences [illegible] [illegible] graphical [illegible] and summary measurements [illegible] [illegible] [illegible] and [illegible]

[illegible] scattering coefficient [illegible] measure [illegible] [illegible] [illegible] [illegible] measurements were made [illegible] having [illegible] [illegible] [illegible] [illegible] (4.1)

4.3 Supplementary Data Entries

[illegible] additional [illegible] have [illegible] information [illegible] the [illegible] visibility reported by the weather service and [illegible] abstracted from Table [illegible]. The second is the ground level scattering coefficient [illegible] measured by the [illegible] approximately [illegible] [illegible] [illegible] NB [illegible] [illegible]

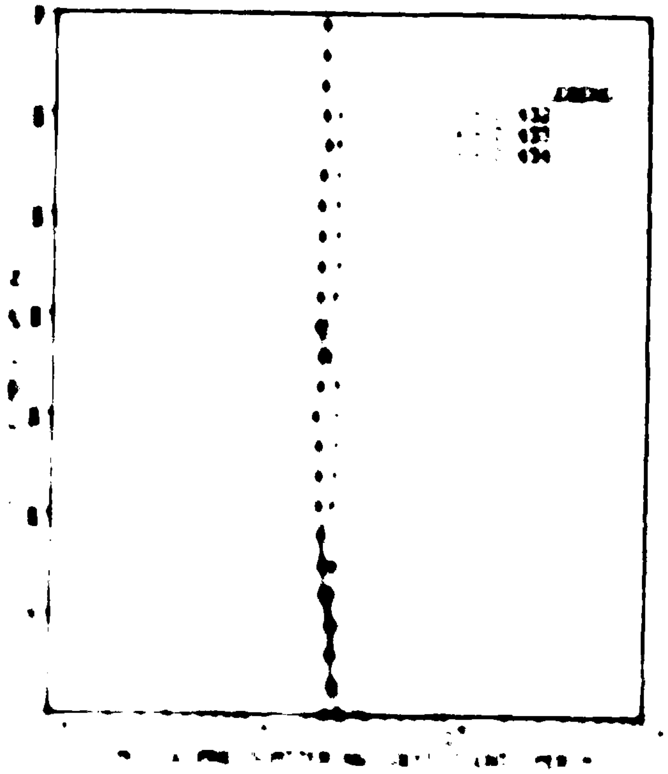
[illegible] as discussed by Douglas and Young [illegible] [illegible] (19[illegible]) and Gordon (1979). A [illegible] between these measured values and the [illegible] made by the [illegible] [illegible] [illegible] all the [illegible] [illegible] meteorological [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] practical procedure [illegible] adequate [illegible] data [illegible] [illegible] [illegible] made [illegible] [illegible] are however included [illegible] supplementary [illegible] the reader's [illegible]

The [illegible] [illegible] [illegible] [illegible] scattering [illegible] These measurements are made [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Table 4. These [illegible] comparisons [illegible] [illegible] [illegible]

The final supplementary [illegible] [illegible] [illegible] These [illegible] [illegible] extracted [illegible] Table 4 and [illegible] [illegible]

[illegible]

[illegible]



[illegible]

[illegible]

[illegible]

[illegible]

Table 4.1

APPROACH PROFILES - TABULAR

[illegible]

Winter 1970

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	
[illegible]		[illegible]	
[illegible]		[illegible]	
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[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]
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[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]			[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Summer 1970

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	
[illegible]		[illegible]	[illegible]	
[illegible]		[illegible]	[illegible]	
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[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
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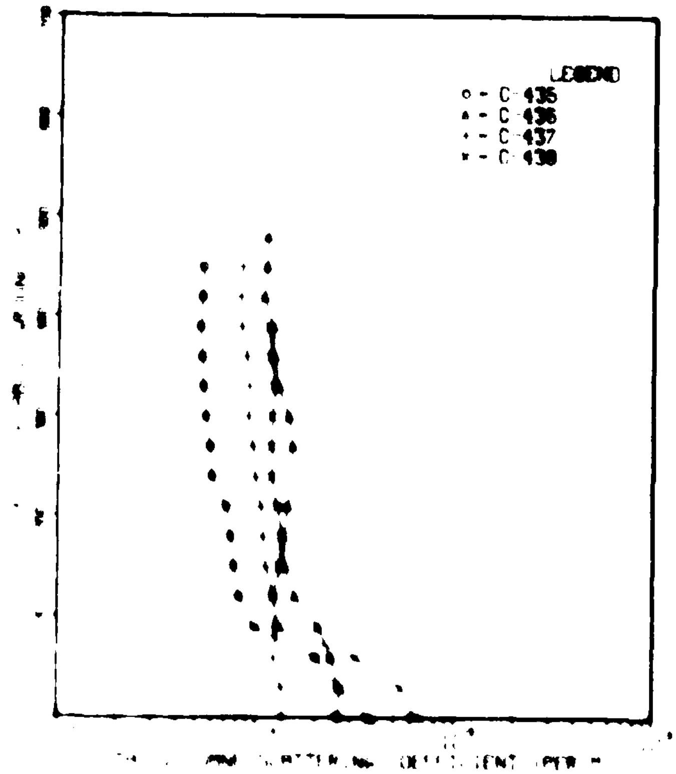
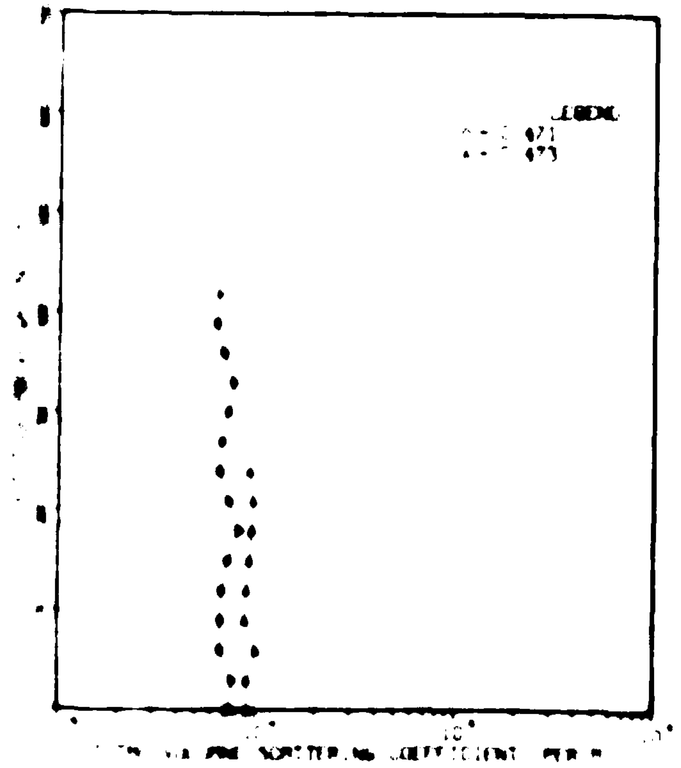
Fig. 4.2

APPROACH PROFILES - GRAPHICAL



Memmingen, Germany

Winter 1978



Memmingen, Germany

Summer 1978

Table 4.2

APPROACH PROFILES - TABULAR

Memmingen, Germany

Winter 1978

Total Volume Scattering Coefficient (m⁻¹)

Altitude (m) AGL	C 435	C 436	C 437	C 439
480		1.10[illegible]E-04		
450	5.273E-05	[illegible]E-04	8.70[illegible]E-05	
420	5.299E-05	1.083E-04	8.227E-05	
390	5.1[illegible]E-05	1.197E-04	8.321E-05	1.147E-04
360	5.27[illegible]E-05	1.215E-04	8.863E-05	1.109E-04
330	5.[illegible]E-05	1.287E-04	9.167E-05	1.227E-04
300	5.[illegible]E-05	1.4[illegible]E-04	9.077E-05	1.192E-04
270	5.863E-05	1.516E-04	9.5[illegible]E-05	1.184E-04
240	5.[illegible]E-05	1.476E-04	9.842E-05	1.186E-04
210	7.[illegible]E-05	1.430E-04	1.056E-04	1.275E-04
180	7.465E-05	1.[illegible]E-04	1.081E-04	1.190E-04
150	7.721E-05	1.[illegible]E-04	1.116E-04	1.100E-04
120	8.[illegible]E-05	1.982E-04	1.239E-04	1.218E-04
90	9.817E-05	2.0[illegible]E-04	1.261E-04	1.299E-04
60	2.[illegible]E-04	2.411E-04	1.212E-04	1.231E-04
30	[illegible].671E-04	2.613E-04	1.351E-04	5.411E-04
0	2.[illegible]E-04	1.[illegible]E-04	1.356E-04	6.409E-04
Visibility (km)	≥11.2	≥11.2	≥11.2	5
Visual Range (km)	1[illegible]	8	22	5
Illumination (lux)	5100	14800	26900	2100
Landing Time (GMT)	0941	1524	1158	1456

Memmingen, Germany

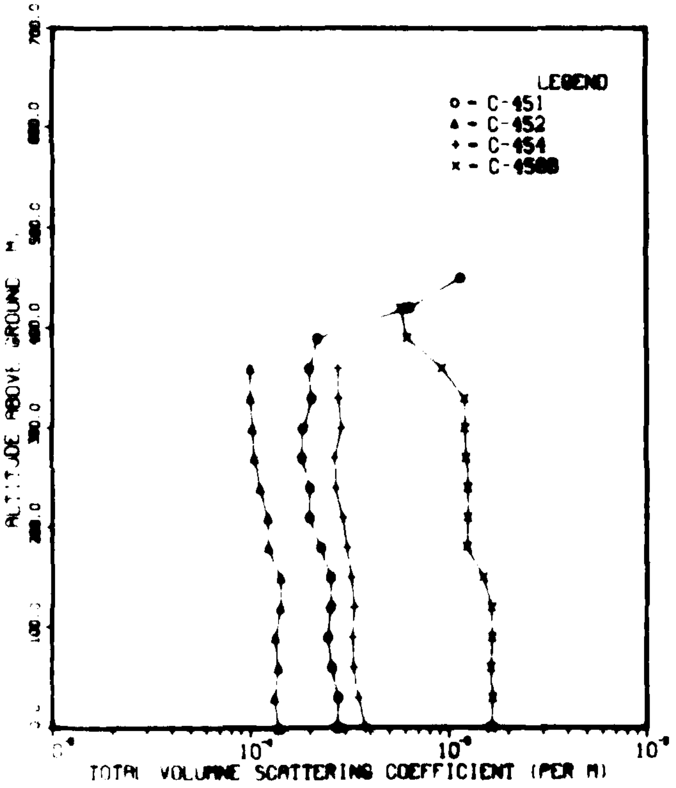
Summer 1978

Total Volume Scattering Coefficient (m⁻¹)

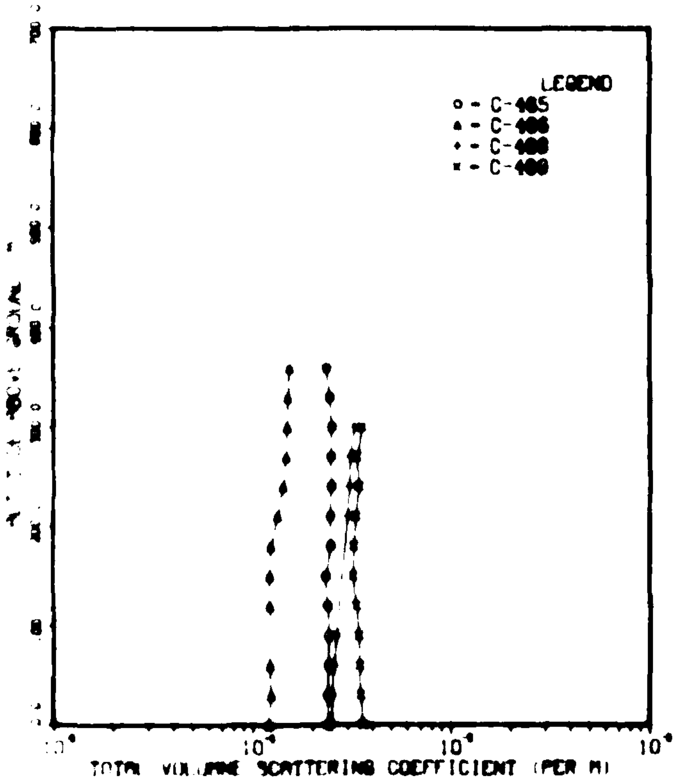
Altitude (m) AGL	C 471	C 473
420	6.[illegible]E-05	
390	6.183E-05	
360	5.[illegible]E-05	
330	[illegible]	
300	[illegible]	
270	6.671E-05	
240	6.[illegible]E-05	9.302E-05
210	7.[illegible]E-05	9.605E-05
180	8.[illegible]E-05	9.[illegible]E-05
150	7.175E-05	9.[illegible]E-05
120	6.677E-05	8.[illegible]E-05
90	6.663E-05	8.812E-05
60	6.621E-05	1.012E-04
30	7.610E-05	9.[illegible]E-05
0	7.1[illegible]E-05	9.117E-05
Visibility (km)	≥11.2	≥11.2
Visual Range (km)	41	11
Illumination (lux)	90100	14000
Landing Time (GMT)	1030	1616

Fig 4-3

APPROACH PROFILES - GRAPHICAL



Wunstorf, Germany
Winter, 1978



Wunstorf, Germany
Summer, 1978

Table 4.3.

APPROACH PROFILES - TABULAR

Wunstorf, Germany

Winter 1978

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1}) C451	C452	C454	C456B
450	1.130E-03			
420	6.[illegible]E-04			5.673E-04
390	2.154E-04			6.086E-04
360	1.940E-04	9.892E-05	2.[illegible]E-04	9.132E-04
330	2.011E-04	9.984E-05	2.743E-04	1.192E-03
300	1.811E-04	1.0204	3.050E-04	1.210E-03
150	2.515E-04	[illegible]400E-04	3.100E-04	1.479E-03
120	2.527E-04	1.407E-04	3.316E-04	1.639E-03
90	2.451E-04	[illegible]120E-04	3.360E-04	1.656E-03
60	2.[illegible]72E-04	1.300E-04	3.300E-04	1.614E-03
30	2.750E-04	1.389E-04	3.405E-04	1.653E-03
0	2.720E-04	1.389E-04	3.783E-04	1.642E-03
Visibility (km)	≥11.2	≥11.2	≥11.2	2.5
Visual Range (km)	13	21	8	2
Illumination (lux)	41600	6800	41200	1900
Landing Time (GMT)	445	1608	1414	1617

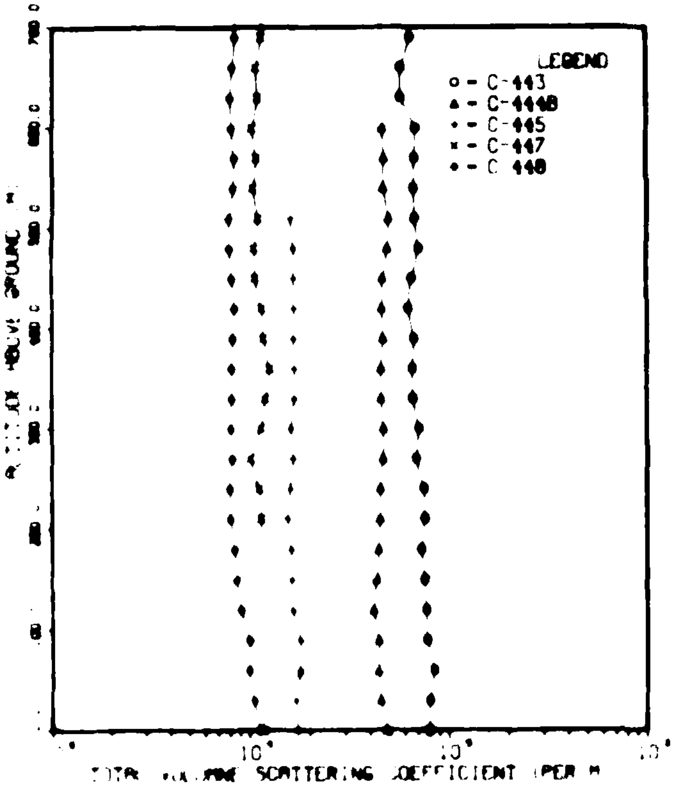
Wunstorf, Germany

Summer 1978

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1}) C465	C466	C468	C469
360	2.364E-04	[illegible]542E-04		
330	2.461E-04	[illegible]502E-04		
300	2.501E-04	[illegible]494E-04	1.240E-04	1.555E-04
270	2.481E-04	[illegible]479E-04	1.100E-04	1.362E-04
240	2.[illegible]E-04	[illegible]417E-04	1.051E-04	1.420E-04
210	[illegible]470E-04	[illegible]E-04	[illegible]322E-04	1.111E-04
180	2.402E-04	[illegible]364E-04	[illegible]924E-04	1.257E-04
150	2.360E-04	[illegible]270E-04	2.026E-04	1.224E-04
120	2.183E-04	[illegible]221E-04	2.170E-04	1.136E-04
90	[illegible]	[illegible]220E-04	2.610E-04	1.400E-04
60	[illegible]E-04	[illegible]210E-04	2.556E-04	1.400E-04
30	2.301E-04	[illegible]245E-04	2.527E-04	1.516E-04
0	[illegible]166E-04	[illegible]280E-04	2.[illegible]E-04	1.601E-04
Visibility (km)	≥11.2	≥11.2	≥11.2	≥11.2
Visual Range (km)	12	25	12	8
Illumination (lux)	21500	86900	71200	70600
Landing Time (GMT)	[illegible]	1401	1314	1600

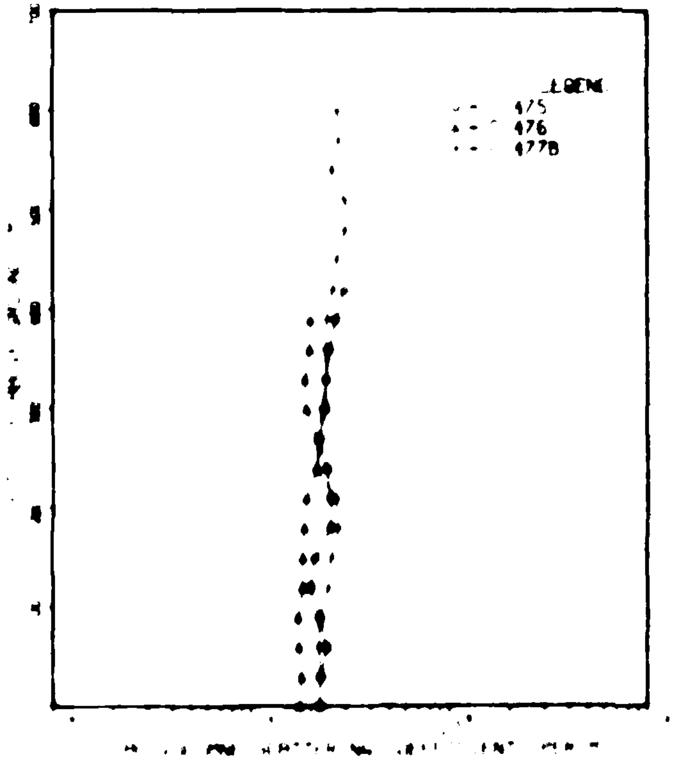
Fig 4.4

APPROACH PROFILES - GRAPHICAL



Mildenhall, England

Winter 1978



Mildenhall, England

Summer 1978

Table 4.4.

APPROACH PROFILES - TABULAR

Mildenhall, England

Winter 1978

Total Volume Scattering Coefficient (m⁻¹)

Altitude (m AGL)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
810				[illegible]	
780				[illegible]	
750				[illegible]	
720				[illegible]	[illegible]
690	[illegible]			[illegible]	[illegible]
660	[illegible]			[illegible]	[illegible]
630	[illegible]			[illegible]	[illegible]
600	[illegible]	[illegible]		[illegible]	[illegible]
570	[illegible]	[illegible]		[illegible]	[illegible]
540	[illegible]	[illegible]		[illegible]	[illegible]
510	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
480	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
450	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
420	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
390	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
360	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
330	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
270	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Visibility (km)	[illegible]	[illegible]	[illegible]		[illegible]
Visual Range (km)	[illegible]	[illegible]			[illegible]
Illumination (lux)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Landing Time (GMT)	[illegible]	624	[illegible]	[illegible]	[illegible]

Mildenhall, England

Summer 1978

Total Volume Scattering Coefficient (m⁻¹)

Altitude (m AGL)	[illegible]	[illegible]	[illegible]
600			[illegible]
570			[illegible]
540			[illegible]
[illegible]			[illegible]
480			[illegible]
[illegible]			[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
300	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
180	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
90	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
Visibility (km)	[illegible]	[illegible]	[illegible]
Visual Range (km)			[illegible]
Illumination (lux)		[illegible]	[illegible]
Landing Time (GMT)	[illegible]	[illegible]	[illegible]

5. DATA DISCUSSION

As noted in the introductory remarks of section 1 the accurate specification of the atmospheric volume scattering characteristics at very low altitudes can be critical to the determination of slant path contrast transmittances through this near surface regime. It is of major importance for one to know (or be able to reliably deduce) the occurrence of major variations in the vertical structure of the atmospheric aerosol. The flight data represented in the earlier referenced reports (Johnson and Gordon, 1980, etc.) have provided extensive samples of these variations and thus have served as the case studies required for developing reasonable modeling representations. A preliminary discussion of a proposed modelling technique was originally discussed in Johnson *et al.* (1979), has been amplified upon in Johnson and Hering (1981) and is described further in Hering (1981).

Since the profile data upon which the Hering model was developed terminated at 500 to 1000 ft (150-300m) above the ground, the confidence with which one could specify the low level scattering properties from these data was somewhat compromised. The data presented in section 4 of this current report specifically address the resolution of the uncertainty in this specification. They support the [illegible] in most cases in-situ measurements of [illegible] scattering coefficient made within the [illegible] ACT altitude regime may be reliably extrapolated [illegible] to the surface with only marginal risk of [illegible] in the context of overall model performance. [illegible] of the [illegible] winter and summer profiles [illegible] section 4 [illegible] three of the winter measurements [illegible] show marked increases in low level [illegible]. In addition [illegible] minor increase at the surface [illegible] flight 434 (winter, Sigonella) but [illegible] deep [illegible] extensive shift as is indicated in [illegible] measurements. The specific conditions [illegible] these four very low altitude phenomena [illegible] been [illegible].

[illegible] other characteristics of this admittedly limited [illegible] bear additional [illegible] spread in the seasonal [illegible] coefficient magnitudes. With the singular [illegible] of the Sigonella [illegible] the winter measurements [illegible] considerably broader variation in scattering coefficient values than do the summer measurements. [illegible] the [illegible] data and is [illegible] with greater [illegible] sample increases. As [illegible] for each flight, these data [illegible] measurements for the most part and [illegible] well mixed vertically stable [illegible] reflect the near surface conditions [illegible] early morning or evening heavy [illegible].

5.1 Summary

Twenty-nine vertical profiles of the photopic atmospheric volume scattering coefficient representing both winter and summer conditions at four separate European aerodromes have been presented for evaluation. The basic question to be addressed is whether or not the scattering coefficient profile remains reasonably constant as one approaches the surface from an altitude of several hundred meters, and if not, what is the character of the vertical structure. These data indicate that in twenty-six out of twenty-nine instances the profile is essentially constant in value and thus the modelling approach proposed by Hering (1981) is in fact an appropriate procedure. The identification of the conditions resulting in the three profiles showing abrupt near surface increases in haze should be addressed as a separate problem when the larger four season data base has been developed.

6. ACKNOWLEDGEMENTS

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APPENDIX A

METEOROLOGICAL GLOSSARY & ABBREVIATIONS

SKY AND CEILING

[illegible]

[illegible]

[illegible]

VISIBILITY (VV)

Reported in [illegible]

WEATHER AND OBSTRUCTION TO VISION SYMBOLS

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Blowing dust	[illegible]	[illegible]
[illegible]	Blowing sand	[illegible]	Rain
[illegible]	Blowing snow	[illegible]	Rain showers
[illegible]	Fog		Snow
[illegible]	Sleet	[illegible]	Snow grains
[illegible]	Sleet showers	[illegible]	Snow pellets
[illegible]	[illegible]	[illegible]	Snow showers
[illegible]	[illegible]		Thunderstorms
[illegible]	[illegible]	[illegible]	Freezing drizzle
[illegible]	[illegible]	[illegible]	Freezing rain

CLOUD ABBREVIATIONS

Ac	Altocumulus	[illegible]	Cirrostratus
As	Altostratus	[illegible]	Cumulus
[illegible]	Cumulonimbus	Ns	Nimbostratus
[illegible]	Cirrocumulus	[illegible]	Stratocumulus
[illegible]	Cirrus	[illegible]	Stratus

WIND

[illegible] of degrees from true north, speed in meters per second (mps). A [illegible] indicates calm. A [illegible] indicates gusts. A [illegible] indicates squall. Peak speed of gusts when reported [illegible]. The [illegible] indicates wind shift and its time of occurrence.

Examples: [illegible] degrees, [illegible] mps
[illegible] degrees, [illegible] mps, peak speed in gusts of [illegible] mps

[illegible]

RELATIVE HUMIDITY (RH)

Reported in percent and computed from temperature and dewpoint.

APPENDIX B

VISIBILITY LABORATORY CONTRACTS AND RELATED PUBLICATIONS

Previous Related Contracts:
F19628-73-C-0013, F19628-76-C-0004

PUBLICATIONS

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1972), "Airborne Measurements of Optical Atmospheric Properties in Southern Germany", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 72-64, AFCRL-72-0255.

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